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## Cure Cycle Evaluation for Multilayer Printed Wiring Boards

By J. W. Lula

Published June 1980

Topical Report

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# CURE CYCLE EVALUATION FOR MULTILAYER PRINTED WIRING BOARDS

BDX-613-2392, Topical Report, Published June 1980

Prepared by J. W. Lula

The cure cycle for multilayer printed wiring boards (PWBs) made from general-purpose, fire-retardant epoxy/glass (GF) material has been evaluated for the optimum delamination resistance at soldering temperatures. The results show that, for the epoxy resin system used to manufacture multilayer PWBs at Bendix Kansas City, a wide range of cure cycle variations has a minimal effect on delamination resistance.

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## SUMMARY

With respect to the delamination resistance of multilayer printed wiring boards (PWBs) made from GF material, changes in lamination pressures, temperatures, and times have minimal effect. Cure cycles evaluated ranged from 15 minutes at 149°C up to 60 minutes at 204°C, and pressures ranged from 690 to 4830 kPa. At the extremes undesirable results were noticed, such as low glass transition temperatures and slightly reduced delamination resistance.

Because changes in lamination pressures, temperatures, and time have minimal effect, the results can be used to increase multilayer production by reducing the lamination time. The cure cycle can be reduced from 60 minutes to 45 minutes without a reduction in quality.

## DISCUSSION

### SCOPE AND PURPOSE

This work is part of a long term project which was initiated to develop a lamination process that would enable Bendix Kansas City to consistently produce ultrathin multilayer printed wiring boards (PWBs) made from GF material (epoxy/glass, general purpose, fire retardant) which are free from delamination problems. In addition, the information learned would be used to optimize the lamination process for increased productivity.

### PRIOR WORK

Prior work on this project involved developing a quantitative test method for measuring the delamination resistance of multilayer PWBs at soldering temperatures and developing improved material handling/preparation techniques for lamination. Delamination resistance is the length of time a multilayer will withstand soldering temperatures without delaminating.

Thermal mechanical analysis (TMA) is the test method developed for measuring delamination resistance.<sup>1</sup> TMA requires minimal sample preparation (a sheet metal hand punch will suffice), takes less than 20 minutes, and may be performed on production panels if desired. Besides measuring delamination resistance, TMA also measures the glass transition temperature of the resin.

The material handling and preparation techniques that improve the delamination resistance are prepreg conditioning and innerlayer surface treatment.<sup>2</sup> Prepreg conditioning involves removing moisture and maintaining the prepreg in a dried condition for lamination. Innerlayer surface treatment involves converting the copper circuitry surfaces to an oxide, which passivates the copper and roughens the bonding surface. The implementation of prepreg conditioning and innerlayer surface treatment in the Bendix manufacturing process has improved the reliability of multilayer PWBs, and, in fact, delaminations of the type which initiated this project no longer occur. Also, evidence exists that the multilayer PWBs made with the current process have improved resistance to plated-through-hole cracking during thermal cycle testing.

### ACTIVITY

Efforts to increase the delamination resistance of multilayer PWBs manufactured at Bendix have continued. Following prepreg conditioning and innerlayer surface treatment, the next logical area to investigate was the lamination cure cycle. Recent work on this

project has determined the effect of lamination pressure, temperature, and time on the delamination resistance of multilayer PWBs. This work was divided into two parts. The first part involved time-temperature effects, and the second part involved pressure effects.

### Time-Temperature Effects

The normal cure cycle for laminating multilayer PWBs at Bendix is 60 minutes at 182°C, using a preheated press. Generally, PWB industry practice is 45 minutes at 171°C. The range for this evaluation was from a minimum of 15 minutes at 149°C to a maximum of 60 minutes at 204°C. Time-temperature combinations beyond these values were judged to be impractical and not realistic.

Time-temperature effects were evaluated by laminating 200- by 250-mm multilayers panels as shown in Figure 1. The prepreg was conditioned in dry nitrogen for 24 hours to remove moisture prior to lamination, and the innerlayers were black oxide-coated following standard process procedures. The lamination pressure was 2000 kPa, which is the normal laminating pressure. After the specified times, the test panels were taken hot from the press (no cool-down cycle) and allowed to air cool before removing the lamination plates. No post-cure was used. Once laminated, each panel was tested for delamination resistance ( $t_{260}$ ) and resin glass transition temperature ( $T_g$ ) by TMA.

The  $T_g$  of these panels are shown in Table 1. At 149°C, none of the times tried resulted in an adequately cured panel, nor did the 160 and 171°C temperatures at the shorter times. These time-temperature combinations are not recommended. The remaining combinations do not clearly point to an optimum cure, which suggests the resin system is relatively tolerant of a wide range of time-temperature cure combinations.

The delamination resistance ( $t_{260}$ ) is shown in Table 2. All the time-temperature combinations resulted in acceptable delamination resistance, even those combinations showing insufficient cure. Table 2 indicates that the higher temperature-longer time cure show a trend toward reduced delamination resistance. As with the  $T_g$ , the delamination resistance is relatively unaffected by variations in time-temperature cure combinations.

### Lamination Pressure Effects

As a multilayer PWB is laminated, the resin in the prepreg heats up, melts, and flows. As the resin flows, it fills voids and wets the core layers, providing interlaminant adhesion upon completion of cure. Excess resin is squeezed out of the lamination package. The amount of squeeze-out (flow) depends on the lamination pressure,

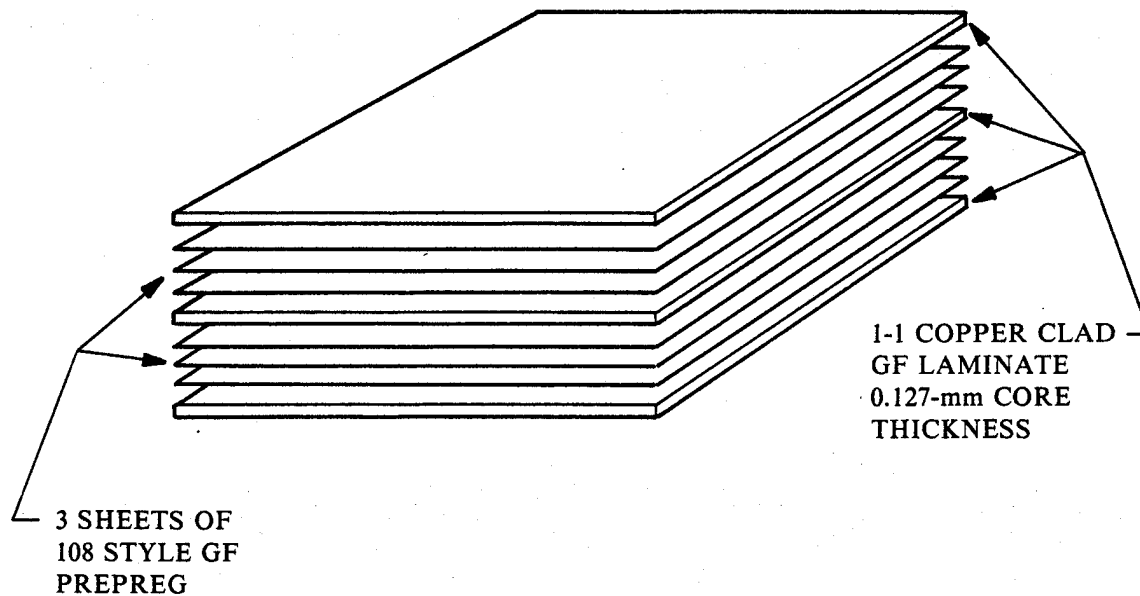
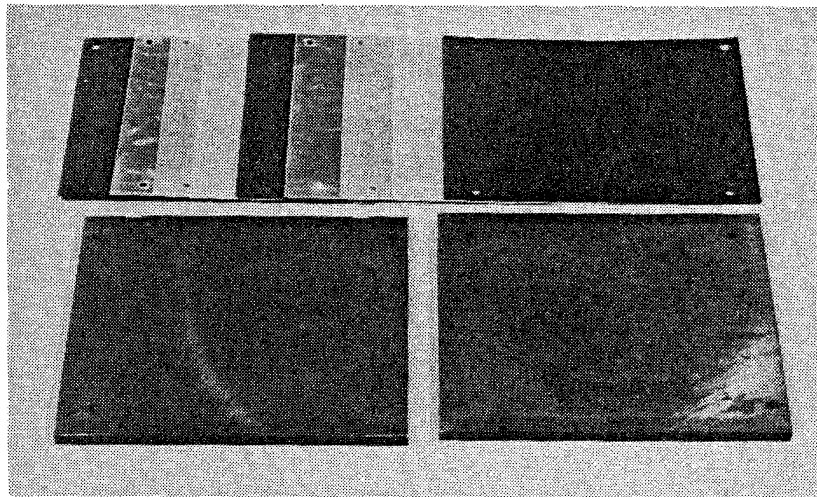


Figure 1. Test Panel Layup

panel size, and the degree of B-staging of the prepreg. Some manufacturers of multilayer PWBs feel that a controlled amount of flow is desirable and provides maximum interlaminant adhesion. These manufacturers adjust lamination pressure according to panel size to maintain a constant flow. The intent of this study was to determine the relationship of flow, lamination pressure, panel size, and adhesion (delamination resistance).

Table 1. Glass Transition Temperature (°C) for Various Lamination Times and Temperatures

Time (Min)	Temperature (°C)					
	149	160	171	182	193	204
15	105*	107*	112*	127	127	134
30	110*	115*	132	128	132	130
45	120*	131	127	129	140	137
60	119*	125	126	131	129	125

\*Insufficient cure.

Table 2. Delamination Resistance (Minutes) for Various Lamination Times and Temperatures

Time (Min)	Temperature (°C)					
	149	160	171	182	193	204
15	5.8	5.9	5.1	6.5		6.7
30	6.2	6.1	5.3	5.0	6.3	5.6
45	5.7	5.0	5.0	6.6	4.8	4.6
60	4.7	5.9	5.5	4.5	4.0	4.3

The results are given in Table 3. Pressures above 2070 kPa for some 300- by 300-mm panels could not be obtained because of the limitations of the lamination press. The percent resin flow behaved as expected; increased lamination pressure brought about higher flow, and, at the same pressure, larger panels had reduced flow. Panel thickness also behaved as expected; increased pressure resulted in decreased thickness.

In spite of the variations in resin flow, panel size, and lamination pressure, delamination resistance was not noticeably affected. The results did not follow a trend, and variations observed easily could be caused by slight variations in operator technique during prepreg conditioning and layup.

#### ACCOMPLISHMENTS

Cure cycle variations have been evaluated for their effect on delamination resistance of multilayer PWBs made from GF material. The evaluation shows that the GF resin system is relatively insensitive to variations in the cure cycle. Subsequently, this information can be used to increase the productivity of multilayer PWBs by shortening the length of cure cycle without reducing quality.

Table 3. Effect of Lamination Pressure

Lamination Pressure (kPa)	Resin Flow (Percent)	Finished Thickness (mm)	Delamination Resistance, $t_{260}$ (Min)
150- by 230-mm Panel			
690	10.7	0.94	2.2
1380	12.6	0.92	2.3
2070	16.8	0.88	2.5
2760	20.0	0.87	2.4
3450	21.7	0.86	3.0
4140	25.3	0.85	2.5
4830	29.7	0.88	3.1
200- by 250-mm Panel			
690	8.7	0.95	2.1
1380	11.8	0.93	2.7
2070	15.4	0.90	2.9
2760	16.3	0.90	2.7
3450	18.4	0.89	3.7
4140	20.8	0.86	2.7
4830	21.3	0.87	2.5
300- by 300-mm Panel			
690	3.2	0.97	2.4
1380	7.4	0.94	2.4
2070	10.6	0.92	3.3

## REFERENCES

<sup>1</sup>J. W. Lula, Testing the Interlaminant Adhesion of Multilayer Printing Wiring Boards (Topical Report). Bendix Kansas City: BDX-613-2011, September 1978 (Available from NTIS).

<sup>2</sup>J. W. Lula, Improving Delamination Resistance of Multilayer Printed Wiring Boards (Topical Report). Bendix Kansas City: BDX-613-2413, March 1980 (Available from NTIS).

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ELECTRICAL: Delamination Resistance

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